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Agronomy Guide

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Soybean Fertilization in Indiana

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Soybean acreage in Indiana has increased rapidly since 1950. Research at Purdue University has shown that, on a percentage basis, soybeans respond to liming and phosphorus (P) and potassium (K) fertilization as much as corn. However, according to USDA Statistical Reporting Service figures, only about 1/2 of the Indiana soybean acreage is presently being directly fertilized. Even with the residual value of fertilizers applied to corn in a corn-soybean rotation, there is concern that Indiana soybean acreage may not be receiving adequate amounts of fertilizers, particularly K.

The dry matter and nutrient composition of a 60-bushel-per-acre soybean crop is shown in Table 1. These values illustrate the large amount of nutrients utilized by soybeans and underscore the need for a well-designed fertilization program to ensure that soil fertility is not a yield-limiting factor.

Soil Testing

The key to a profitable soybean fertilization program is soil testing. Soil tests are primarily used in Indiana to make lime and P and K fertilizer recommendations. Since soils tend to be quite variable in many parts of Indiana, it is important to set up sampling patterns which address this variability. Modern soil surveys have soil maps superimposed on aerial photographs and are an excellent tool to use to establish sampling areas based on soil properties.

Purdue fertilizer and lime recommendations are based on soil tests calibrated to a 9-inch sampling depth. For most accurate recommendations, a similar sampling depth is recommended in most situation.

P and K concentrate near the surface in fields where reduced tillage has been used for some time. This has not led to any particular problems except in drought years. Under dry conditions root activity in the surface portions of the soil can be reduced, causing reductions in P and K uptake. This can result in yield reductions.

One sampling method proposed for use in very reduced tillage systems is to split a normal 9-inch core into 0- to 4-inch and 4- to 9-inch subsamples representing the surface 4 inches of the root-zone and the lower 4- to 9-inch depths of the traditional plow layer. If the 4- to 9-inch subsurface zone is low or very low in P or K, then the use of deeper fertilizer placement techniques, or tillage, to mix plant nutrients into that zone may be called for.

A second sampling method that is sometimes used on no-till fields is to sample the surface 1 to 2 inches of soil for pH only. When corn is grown in rotation with soybeans and nitrogen fertilizers used for corn are applied directly to the soil surface, the surface few inches of soil can be acidified very quickly. Thus, sampling the surface on a regular basis can detect these changes and prevent this low pH from adversely affecting plant growth or herbicide activity.

pH and Liming

The soybean is a legume that requires proper pH for nodulation and nitrogen fixation. However, soybeans are not as sensitive to acid soils as alfalfa; thus, they do not need the high pH levels generally associated with alfalfa.

On light-colored upland soils, water pH values from 6.0 to 6.5 are adequate. *Bradyrhizobia japonicum*, the bacteria responsible for nodulation and N fixation, thrive in this pH range, and the supply of calcium and magnesium is also normally adequate at this level.

On dark-colored depressional soils, the suggested water pH range is 5.5 to 6.2. These soils have a high cation exchange capacity (CEC) and will supply adequate calcium and magnesium at these lower pH ranges.

Limestone should only be applied on the basis of a soil test. Raising pH above the recommended range has not proven beneficial in Indiana and, in fact, may induce manganese deficiency, particularly on depressional soils. The dark-colored sands of northern Indiana should not be limed above pH 6.3 to avoid such a problem.

Limestone recommendations are based both on specific fineness of grind and on tillage depth. The current recommendation is to add sufficient lime (25-35 percent of the limestone passing through a 60-mesh sieve) to raise the top 9 inches of soil to pH

6.2-6.4. If fineness of the lime used varies from the standard, the rate should be adjusted accordingly. Table 2 gives the rate adjustments for coarser or finer ground limestone.

Similar adjustments should be made if tillage depths differ significantly from 9 inches. It's important that lime rates be reduced where shallow tillage is used (especially in no-till systems) since the lime will react with a smaller volume of soil. As a general rule, only one-half the normal recommended rate of lime should be applied where no-till is used, and only two-thirds the normal rates with ridge till or chisel plowing.

Nitrogen

As Table 1 shows, a high-yielding soybean crop requires large amounts of nitrogen. Being a legume, soybeans have the ability to fix and utilize atmospheric nitrogen; consequently, nitrogen fertilizer is not recommended for soybean production. A number of experiments have shown that when proper pH and fertility are maintained, N fixation is capable of supplying the N for soybeans in Indiana. The additions of fertilizer N is not economical.

Table 1. Dry Matter and Nutrient Composition of a 60-Bushel-per-Acre Soybean Crop.

Item	Grain	Straw	Stubble & roots	Total
		---lb./a.---		
Dry matter	3,000	3,500	1,500	8,000
Nitrogen (N)	220	70	35	325
Phosphorus (P_2O_5)	50	20	10	80
Potassium (K_2O)	70	45	25	140
Calcium (Ca)	–	–	–	80
Magnesium (Mg)	–	–	–	35
Sulfur (S)	–	–	–	25
Iron (Fe)	–	–	–	1.7
Manganese (Mn)	–	–	–	.6
Zinc (Zn)	–	–	–	.2
Copper (Cu)	–	–	–	.1
Boron (B)	–	–	–	.1
Molybdenum (Mo)	–	–	–	.01

Table 2. Effect of Limestone Fineness on Application Rate.

Liming recommendation from soil test	Actual application rate required if percent passing through a 60-mesh sieve is: 10-24	25-35	36-60	61-100
ton/a.		---ton/a.---		
2	2.5	2.0	1.5	1.5
4	5.5	4.0	3.5	3.0
6	8.0	6.0	5.0	4.5
8	11.0	8.0	6.5	5.5

Phosphorus

Approximately 60 percent of the phosphorus taken up by the soybean plant goes into the grain and is removed at harvest. This represents about 3/4 pound of P_2O_5 per bushel of grain.

Table 3 gives the current P_2O_5 recommendations for various yield goals at different phosphorus soil test levels. For example, the phosphorus recommendation for a field with a Bray P_1 soil test level of 25 pounds P per acre and a 55-bushel yield goal would be 70 pounds of P_2O_5 per acre.

Since phosphorus is not easily lost from the soil, multi-year applications are effective. Thus, in the example, applying 140 pounds of P_2O_5 per acre every 2 years would be as effective as 70 pounds each year.

An increasing acreage of soybeans is being grown with no-till and reduced tillage systems in Indiana. With a minimum of soil mixing to incorporate phosphorus, it is important to try to build soil test levels to the medium to high range before switching to a continuous no-til! or reduced tillage system. If soil tests are in the very low or low range, phosphorus fertilizer applications at rates shown in Table 3 for 3 to 5 years prior to switching tillage systems will build soil test levels to the high range. When phosphorus fertilizers are broadcast on the soil surface, the available phosphorus accumulates in the upper 1 to 2 inches of soil in a no-till system and in the top 4 to 5 inches in a reduced tillage system. This phosphorus may become positionally unavailable to the plants if the top layer of soil dries and the roots are active only in the deeper layers of soil, thus the need for medium to high soil tests throughout the top 6 to 8 inches of soil.

The recommendations in Table 3 are made with the dual objective of (1) meeting the present crop's phosphorus needs and (2) increasing the P level of low phosphorus soils to the medium to high range. Research in Indiana has shown little or no response to increasing soil test levels beyond the high range or to applying phosphorus fertilizer on soils with very high test levels. Consequently, phosphorus fertilization is not recommended on soils with a Bray P_1 test level of 51 pounds P per acre or higher. For those who have a very high soil test and wish to maintain it, Table 3 includes a maintenance recommendation designed to replace the phosphorus removed by cropping.

Potassium

Soybeans are heavy potassium feeders, as noted in Table 1. About half the potassium absorbed by the plant ends up in the grain, which means about 1 1/4 pounds of K_2O are removed in each bushel of grain harvested.

Table 4 gives the current potassium recommendations for various yield goals and soil test levels.

Table 3. Recommended Phosphorus (P_2O_5) Rates for Soybeans Based on Yield Goals and Soil Test Levels.

Soil test level	Bray P_1 test		P_2O_5 rate when bushel-per-acre yield goal is:				
			30-40	41-50	51-60	61-70	71+
	lb./a.	ppm P	---lb. P_2O_5/a.---				
Very low	0-10	0-5	60	80	100	120	120
Low	11-20	6-10	50	70	90	100	100
Medium	21-30	11-15	40	50	70	80	80
High	31-50	15-25	30	30	40	50	50
Very high	51+	26+	0	0	0	0	0
Maintenance recommendations			30	30	40	50	50

Table 4. Recommended Potassium (K_2O) Rates for Soybeans Based on Yield Goals and Soil Test Levels.

Soil test level	Exchangeable potassium		K_2O rate when bushel-per-acre yield goal is:				
			30-40	41-50	51-60	61-70	71+
	lb. K/a.	ppm K	---lb. K_2O/a.---				
Very low	0-80	0-40	100	120	150	180*	180*
Low	81-150	41-75	80	90	120	150	150
Medium	151-210	76-105	50	70	90	120	120
High	211-300	106-150	40	60	70	80	80
Very high	301+	151+	0	0	0	0	0
Maintenance recommendations			40	60	70	80	80

* If Cation Exchange Capacity (CEC) is less than 6 meq./100 g. soil, do not apply more than 150 lb. K_2O per acre in any one year.

The same basic philosophy is used in making potassium recommendations as for phosphorus–namely, providing adequate K for crop growth while building soil fertility to the medium to high soil test levels.

Applying a high rate of K to meet the need of two crops can be done on most Indiana soils. However, since fertilizer K can be converted to unavailable forms on some soils, applications for more than 2 years are discouraged. On light-colored sandy soils with low CEC, K can be lost by leaching. Thus, multi-year applications of potassium should not be used; rather, the potassium should be applied annually in the spring.

Fertilizer Placement

Broadcasting is likely to be the most practical method of applying fertilizer to soybeans. This is especially true where higher rates are being used. Research at Purdue shows that fertilizer does not have to be applied directly to soybeans, and multi-crop applications can be just as effective as annual applications.

Where fertilizer is applied on corn with the purpose of letting soybeans feed on the residual fertility, it is important that enough be applied to meet the needs of the following soybean crop. This means applying both the fertilizer recommended for the corn and the amount recommended for the soybean crop. Where soybeans are double-cropped after wheat, the total fertilizer recommendation must be applied prior to planting the wheat to meet the needs of both the wheat and soybean crops.

Starter or row fertilization is suggested if the soil test levels are low or very low or if only small amounts of fertilizer are to be applied each year. Since soybean plants are very sensitive to concentrations of salt, the banded starter or row fertilizer should be placed at least 2 inches to the side and below the seed. "Pop-up" type placement of fertilizer directly with the seed should not be used. In a White County (Indiana) field test, soybean stands were reduced one-third by a 50 pound per acre pop-up application of 9-23-30 fertilizer.

Deep banding or strip application of "plow-down" fertilizer can be used to increase the utilization of fertilizer on soils with low or very low soil tests. However, research has shown that no response to this placement technique can be expected in soil tests of medium or above.

Micronutrients

Manganese

Manganese is the micronutrient of greatest importance to soybean growers in Indiana. Manganese deficiency is most likely to occur in two soil regions of Indiana, (1) the black sands of the Kankakee River Valley and (2) the heavy depressional soils of northeastern Indiana. Deficiencies have also been noted in heavy depressional soils in other areas of the state, especially where the pH is above 6.2-6.3.

Manganese deficiency can be corrected either by applying a row fertilizer containing manganese, or by applying a foliar (leaf) manganese spray early if deficiency symptoms appear. For mineral soils, 5-8 pounds per acre of elemental manganese can be incorporated into the row starter fertilizer as either manganese sulfate or powdered manganese oxide. (For organic soils, the rate is 10 pounds or more; therefore, consider foliar rather than soil treatment). Since manganese is rapidly converted to unavailable forms, applications must be made annually. Broadcast applications are not recommended.

When manganese fertilizers are mixed with phosphorus fertilizers that have an initial acidic reaction in the soil, such as 0-46-0, banded or row applications of the mixture will maintain manganese availability for a longer time than when mixed with phosphorus fertilizers that have an initial basic reaction in the soil, such as 18-46-0. Banded or row applications of these mixtures may not totally prevent manganese deficiencies but can minimize the number of foliar applications that are needed to correct a deficiency.

The per-acre rate for foliar application is 1-2 pounds of manganese as manganese sulfate (only 1 pound if plants are small). Special care is required if using manganese chelates, since some carriers can cause considerable leaf burn at high rates. Generally, the application rate of chelates is lower than other sources, because of the leaf burn problem. Follow manufacturer's directions when applying any material.

Copper

Soybeans occasionally are found to be copper deficient. Such deficiencies are most apt to occur in acid organic soils, such as the Adrian muck, but can also show up on the black sandy soils of northwestern and north central Indiana.

This micronutrient is generally applied broadcast at a per-acre rate of 3-6 pounds copper as copper sulfate or copper oxide. It can also be banded in row fertilizer at a rate of 2-3 pounds using the same sources, or applied as a foliar spray using 2 pounds basic copper sulfate in a minimum of 30 gallons of water per acre.

Molybdenum

Molybdenum deficiency of soybeans has been found on certain acid prairie soils in northwestern Indiana. The recommended fertilization procedure is to use 1/2 ounce sodium molybdate per bushel of seed as a plant box treatment, or 2 ounces of sodium molybdate in 30 gallons of water per acre as a foliar spray. However, be extremely careful in the application of molybdenum, since 10 parts per million in forage is toxic to ruminant animals.

For additional information on micronutrients, see Purdue Extension Publication AY-239, *Role of Micronutrients in Efficient Crop Production*, available from county Cooperative Extension Service offices.

Plant Analysis

One excellent tool which can be used to monitor the effectiveness of a soybean fertilization program is plant analysis. Plant analysis can also be used to diagnose problems in the field.

The preferred time to sample soybeans for plant analysis is early bloom to when the first pods are visible but less than 1/4 inch in length. Fifty sets of the top fully developed trifoliate leaves should be collected from the same area that soil samples are routinely collected. Normally these would be the leaves attached at the second node below the terminal bud. The leaves alone should be collected. The petioles or stem which connects the leaf to the main stem should be discarded. The leaves should be allowed to wilt and then be packed in a paper or cloth shipping envelope or bag and sent to the testing lab.

The most commonly used method of interpreting plant analysis data is the critical level concept. The critical level is the concentration of a nutrient in a specific plant part at a specific stage of growth, below which yields decrease or deficiency symptoms appear. It is important to note that the critical level varies in different plant parts and at different stages of plant maturity. Make sure when using plant analysis that the person interpreting the results of your samples is aware of the plant part sampled and the stage of growth at the time of sampling.

The critical levels used by the Purdue Soil Testing Lab for interpreting the analysis of soybean leaves sampled prior to pod set are given in Table 5. Nutrient levels in the medium to high range would be considered normal, while those in the very low range would be deficient.

When interpreting plant analysis, keep in mind the effects of growth stage or maturity on nutrient levels. As plants grow, nutrient levels decrease in the older tissue. So if your sample comes back with all nutrients in the low or very low range, it may be that the plants were more mature when sampled, rather than that all nutrients were deficient.

More factors than just soil nutrient content can affect plant nutrient contents. Soil compaction, drought, or pests such as soybean cyst nematodes can also reduce nutrient levels in the plant. When

Table 5. Nutrient levels in soybean leaves used to interpret plant analysis data.[1]

Nutrient	Nutrient level				
	Very low	Low	Medium[2]	High	Very high
			---percent---		
N	<4.00	4.00-4.25	4.26-5.50	5.51-700	>7.00
P	<0.15	0.16-0.25	0.26-0.50	0.51-0.80	>0.80
K	<1.25	1.26-1.70	1.71-2.50	2.51-2.75	>2.75
Ca	<0.20	0.21-0.35	0.36-2.00	2.01-3.00	>3.00
Mg	<0.10	0.11-0.25	0.26-1.00	1.01-1.50	>1.50
			---parts per million---		
Mn	<14	15-20	21-100	101-250	>250
Fe	<30	31-50	51-350	351-500	>500
B	<10	11-20	21-55	56-80	>80
Cu	<4	5-9	10-30	31-50	>50
Zn	<10	11-20	21-50	51-75	>75
Mo	<0.4	0.5-0.9	1.0-5.0	5.1-10.0	>10.0

[1] Upper fully mature trifoliate leaves sampled prior to pod set.
[2] Critical range, below which yields may be limited.

using plant analysis for troubleshooting purposes, it is also helpful to take soil samples from the same sampling areas as the plant samples, and to sample both the problem area and a nearby area with a normal-appearing crop.

Plant analysis is a powerful tool for both diagnosing nutrient deficiencies and monitoring fertility programs. However, to gain the most from this tool, care must be exercised to collect the best possible samples and to interpret the results realistically.

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